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# The Effects of Tactually Induced Unilateral and Bilateral Electric Shock on the Auditory Threshold: An Interpretation Based on Brain Blood-Shift Theory

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# THE EFFECTS OF TACTUALLY INDUCED UNILATERAL AND BILATERAL ELECTRIC SHOCK ON THE AUDITORY THRESHOLD; AN INTERPRETATION BASED ON BRAIN BLOOD-SHIFT THEORY

by

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# CHAPTER I

## INTRODUCTION AND PURPOSE

The theory of Brain Blood-Shift by Conrad Chyatte, is first found in the literature in 1954; however the idea, that brain nourishment levels mediate psychological change, dates back to the ancient Greek physicians. They believed that sleep resulted from decreased blood flow through the carotid arteries which deliver blood to the brain (Castiglioni, 1947).

It has also been suggested that human awareness is mediated by selective activation of specific parts of the brain through locally increased blood supply. In the view of Ramon y Cajal (1895) there is described the process whereby this circumscribed hyperemia is generated; it begins with the contraction of the perivascular neuroglia, which in turn causes the dilation of the brain capillaries. This view seems to be supported by the phenomenon which is seen when, for example, pressure is applied manually to the carotid arteries, and there results a gross drop in general sensory function, sometimes even gradual unconsciousness. The same principle, in reverse fashion, whereby flushing of the head and neck can be seen, seems to be invoked for the use of drugs such as nicotinic acid when there is a desire to offset the disturbed patients sensory and affective depressions. The idea in this case is that cerebral vasodilation acts to arouse the patient psychologically (Beckman, 1961).

Chyatte (1965) offers evidence for his brain blood-shift theory and its relation to intra and intersensory rivalry phenomena, by pointing out that although we receive stimuli from many different sources at the same time, we can nevertheless attend to, or hold in our field of awareness, only a small portion or these at any given moment. For example, as one reads this page, the retinal field receives light from many sources and from many lines of type at the same time. All this occurs quite comfortably; yet real difficulty is experienced when one tries to read and comprehend any two adjacent lines together. The explanation for this is, according to Chyatte, that no brain area mediates awareness without a sufficient share of the individual's blood supply. According to Chyatte's theory, areas of functional localization in the brain, and thus the exogenic and endogenic stimuli to which they respond, are in constant competition for the sharply limited availability of blood-borne metabolites. The difficulty experienced in attempting to attend to several stimuli at once is seen to rest on a transient undernourishment of relatively inactive parts of the brain in favor of parts under effective stimulation. The writer can offer his own example of intrasensory rivalry, which is encountered by pilots who must operate complex aircraft during simulation and actual flights. At times, pilots find it impossible to attend to the terrain outside the cockpit window during low level flight, and at the same time notice an emergency warning light which is blinking brightly directly in front of them. The combination of too many complex stimuli of one type impinging on the organism at the same time, and the theorized relatively "slow" shift of blood within the brain, appear to collectively create a situation which results in the manifest intrasensory rivalry. In complex military systems (because of such human limitations as sensory rivalry) computers, electronic sensing and ferret devices, and decision making contrivances are sometimes used. These types of equipment escape the energy shift problem and can thus do many things at the same time, because electric power is transferred instantaneously and amply to any functional part of such devices.

Blood-shift theory may account for the success of audioanalgesia (Carlin, Ward, Gershon, and Ingraham, 1962). Audioanalgesia is induced in the patient by diverting the blood to the temporal areas of the brain cortex by bilateral stimulation (through earphones) with white noise. In blood-shift terms, the closest area to the temporal auditory brain is then diminished in blood supply, and its function of mediating painful stimuli in the head area is thus hindered or removed entirely. It is interesting that the foot, ankle, etc. pain mediating area of the brain, which is farthest from the auditory brain center, is least affected by this blood-shift. Consequently, Chyatte (1965) says that his blood-shift theory predicts that audioanalgesia becomes less and less effective as the locus of pain shifts cephalocaudally. Chyatte (1966) states that the reason, why audioanalgesia is less effective as the locus of pain is shifted cephalocaudally, is that there is greater competition for blood-borne metabolites between immediately adjacent cortical tissues than there is between more distant loci in the brain. He believes, regarding this competition between brain loci for blood nourishment, that the common difficulty people experience in understanding two or more simultaneous conversations is seen to reflect competition for blood within the limits of the auditory cortex (intratemporal rivalry). Such rivalry should diminish with distance along the cortical surface, the active area drawing little or no blood from more distant loci.

It is a study by Chyatte (1966) which is most similar to the one which the author will undertake. Chyatte offers as a corollary to the predicted decreasing efficiency of audioanalgesia as pain locus shifts cephalocaudally, a suggestion that as painful stimuli, for example electric shocks, are applied caudocephally, the human auditory thresholds will be concurrently elevated. His research showed that auditory thresholds tended to be heightened when shock was applied. The greatest threshold elevation was observed for shock to the cheek (its somatosensory area being closer to the cortical auditory area) more than to the finger or leg. These latter two body parts have their "centers" farther and almost farthest respectively from the auditory area. Incidentally, voltages applied to the finger and leg respectively were about 8.3 and 6.7 times greater than the voltage to the cheek. These results verify a cephalocaudal gradient in tactual-auditory rivalry as predicted from brain blood-shift theory. The phenomenon appears to be quite gross and should be easily and consistently replicable, even with small numbers of subjects. One purpose of this dissertation will be to see if the predicted cephalocaudal gradient in tactual-auditory rivalry is reverified on the basis of brain blood-shift theory when a similar replication of Chyatte's work is attempted wherein more areas of the body are shocked caudocephally.

The text by Penfield and Rasmussen (1947) illustrates that somatosensory tissues for the mouth (gums and tongue) have been found to be closer to the auditory cortex than are those for the cheek, thumb, fingers, palm area and neck (respectively "away" from the auditory cortex). Assuming a blood-shift gradient, auditory threshold may show a patterned progressively increasing hierarchy of elevations as blood is shifted according to a definite descending cortical sequence, such as the following; neck, palm area, fingers, thumb, cheek, upper lip, lower lip, gums, tongue. The author will examine the effects of caudocephally induced shock to these body areas to see if on the basis of brain blood-shift the auditory threshold does show this patterned progressive hierarchy of elevations as shock is applied, and what significant differences may exist among any experimentally elevated thresholds.

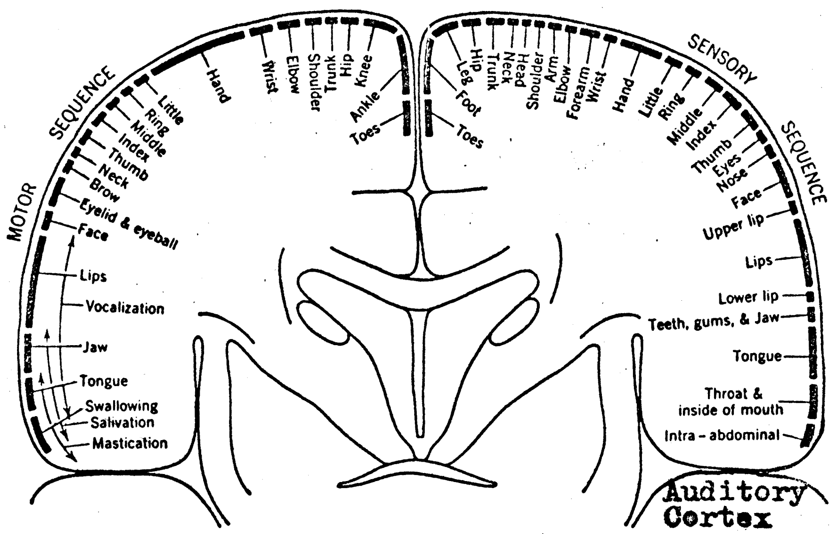
Some auditory pathways decussate (cross over), therefore each ear is represented by cortical tissue on both hemispheres of the brain. Thus, bilateral shock for example left and right sides of the lower lip shocked together, may be expected to shift blood away from the auditory cortex on each hemisphere, to produce a greater threshold elevation than does brain unilateral shock. The author will examine on the basis of blood-shift theory the comparative effects of unilateral and bilateral shock application on the auditory threshold.

From the work of Penfield and Rasmussen as illustrated in Stevens (1951), it appears from an illustrated brain diagram, that the vertical extent of the postcentral gyrus (somatosensory area) devoted to a given area of the body is out of proportion to the area of skin represented. The brain area for the tongue, gums, and lips is far greater than that for the arm, shoulder, trunk of body, or neck. It also appears that brain areas; for example the smaller cortical sensory mediating areas for example the neck, palm aspect of the hand, and then proceeding down the cortex for example all the fingers considered collectively, and then larger areas for upper lips, lower lips, gums, and tongue; generally follow a size pattern downward toward the auditory cortex which becomes larger and larger (Figure 1, page 7). From these observations, Dr. Paul von Ebers, of Loyola University, astutely asks, is it not possible that the reason Chyatte's investigations show that the shock applied to the cheek, for example, seems to have greater effect on the auditory threshold than does shock applied to the tip of the index finger, is because the cortical area for the cheek is larger than that of the index fingertip; and thus the size of the cortical area(s) involved may also contribute to the effects of brain-blood-shift as equally as the effects of proximity between areas. The author will therefore investigate the proximity vs size aspect of Chyatte's Brain Blood-Shift Theory. In turn, also because of the apparent proximity vs size aspect, the author will compare the effects of shocking the neck (a very small cortical area) vs shocking the thumb (a large cortical area). The results of this comparison will be interesting because the neck seems to be more subjectively sensitive than the thumb, thus the stimulation of the larger and cortically closer thumb area may not affect the auditory threshold as much as does the stimulation of the neck.

In summary, the specific aims of this research are to:

1. Reverify on the basis of Chyatte's Brain Blood-Shift Theory that in general, the human auditory threshold will be concurrently elevated when electric shock is applied caudocephally to the skin of various parts of the lower and then the upper part of the body; and that there will be a pattern of threshold elevation which will confirm the existence of an even more extensive cephalocaudal gradient in tactual-auditory rivalry, than Chyatte confirmed.

FIGURE 1




Plane of Central Sulcus

A schematic diagram combining a cross section through the postcentral gyrus (right) and the precentral gyrus (left) in the plane of the central fissure. The diagram shows the motor and sensory sequence of representation in the cerebral cortex of man, determined by electrical stimulation of conscious patients at operation.

2. On the basis of brain blood-shift theory, examine what significant differences may exist among any experimentally elevated auditory thresholds which resulted from unilaterally shocking, a) areas separated about the head vs an area separated significantly from the head, or b) areas which are seemingly differentially sensitive; such as, respectively, 1) the face areas--cheek, upper lip, lower lip each compared with the palm, with fingers 5 and 4, 2) the neck compared with the thumb.
3. On the basis of brain blood-shift theory, examine what significant differences may exist among any experimentally elevated auditory thresholds which resulted from unilaterally shocking areas which are, a) separated about the head area plus which are differentially sensitive and whose tissues are inside vs outside the body, b) separated about the head area vs an area which is significantly separated from the head, plus which are differentially sensitive and whose tissues are inside vs outside the body; such as, respectively, a) the mouth area (example, gums and tongue) each compared to the cheek, b) the mouth area compared with the palm (with fingers 5 and 4).
4. Investigate the proximity to the auditory cortex vs the size of cortical area aspect of the Brain Blood-Shift Theory, by studying the effects on the auditory threshold of stimulating a body area whose cortical representation may be considered to be close and large, or close and small, or distant and large, and so on; and then making the following types of comparisons

between areas:

a. large-close vs large-distant (or tongue vs palm with fingers 5, 4),

b. large-close vs small-close (or tongue vs lower lip),

c. large-close vs small-distant (or thumb vs neck),

d. large-distant vs small-distant (or palm, etc. vs neck),

e. small-close vs small-distant (or lower lip vs neck),

f. large-distant vs small-close (or palm, etc. vs lower lip),

5. On the basis of brain blood-shift theory, study the comparative effects of unilateral vs bilateral stimulation on the auditory threshold to observe whether a) bilateral stimulation does or does not effect a greater threshold elevation than unilateral stimulation, when:

1. neck vs sides of neck
2. palm vs palms
3. thumb vs thumbs
4. cheek vs cheeks
5. upper lip vs upper lips
6. lower lip vs lower lips
7. a point vs points on the gums
8. a point vs points on the tongue

are compared,

b) bilateral stimulation also follows a pattern of a cephalo-caudal gradient in tactual-auditory rivalry,

c) bilateral influences are greater or not when unilateral large-close vs large-distant, and bilateral large-close vs large-distant type comparisons are made for all possibilities.

## CHAPTER II

## REVIEW OF RELATED RESEARCH

Human blood-shift during reading and other visual tasks has been demonstrated by Fulton (1928). In this study, Fulton describes a case where blood-vessel occlusion, caused by a tumor at the visual cortex, produced a murmur detectable through the skull by ausculation. This murmur was most audible to the examiner during increased levels of visual activity.

Blood-shift has been observed in animals. Darrow and Graf (1945) state that implantation of transparent cranial windows over the cortex of cats, allowed examiners to observe reddening and blanching which occurred as the result of drugs, hyperventilation, and temperature changes. Associated changes in electroencephalographic frequency and potential were also reported. Glover, et. al (1965) show that electrocortical activity was also shown to be positively correlated with blodd glucose levels in dog brains isolated alive in vitro

The work of Kennedy (1959) shows that electroencephalographic alpha waves appear maximally when the human eyes are closed. As the eyes are opened, these waves tend to disappear. Corresponding changes in intensity and localization are readily discernable in EEG readings as the subject's attention is shifted and focused. In terms of blood-shift theory, the presence of generalized high levels of alpha activity, in the resting subject with eyes closed, indicates a relatively high availability of blood throughout the cerebral cortex. As the subject's eyes open, adjacent areas become impoverished as blood shifts to the occipital brain visual-projection area. It was suggested that this transient disturbance in general availability of cortical nourishment underlies the abrupt drop in alpha activity as the eyes are opened.

Activation of any cortical locus, according to Shepard (1906), has been found to result in massive blood shift to the brain as a whole; therefore with 1) blood rivalry at a minimum between the relatively separated visual cortex and the somatosensory area, and 2) simultaneous stimulation of both areas, the results should be, in the light of brain blood-shift theory that perceptual rivalry should be minimal and that intersensory facilitation should be maximal. The first inference is supported by the fact that people have very little difficulty in seeing and feeling an object simultaneously. In support of the second inference, regarding intersensory facilitation, Symons (1963) illustrates many cases where auditory-visual (temporal-occipital) facilitation was evident. He illustrated the effects of various auditory stimuli on visual sensitivity. The author can offer some evidence, in reverse fashion, that as visual stimulation becomes increasingly greater for pilots, auditory sensitivity also becomes greater. Thus the use of NORVIPS (Northrop Voice Interuption Priority System) is justified in complex aircraft where most pilot tasks are visual, demanding, and critical. Common sense also reminds one, that he can attend to another's facial expression while perceiving the meaning of the other's speech.

Chyatte (1967) uses his brain blood-shift theory to account for the transition from unconscious to conscious activities during hypnosis, and bizarre visual and auditory hullucinations reported by people under sensory deprivation, e.g., darkness and silence. It an undeprived environment, brain blood should be in the cortical sensory projection areas; conversely, during deprivation, metabolites should become more readily available to the temporarily less active surrounding parts. Thus more nourishment becomes available to the surrounding visual-association area (peristriate and parastriate cortex). Increased association area nourishment, and its consequent activation, triggers visual hullucinations not unlike those produced by electrostimulation of these tissues done during brain surgery. Consistent with this interpretation, Zubek and Welch (1963) found that people under sensory deprivation manifested decreased EEG alpha frequency when hullucinatory experiences began.

The examination of the literature illustrates that Chyatte has done an admirable job in logically developing his brain blood-shift theory, and then relating it to progressively more observable phenomena, which in turn have borne out his predictive inferences and those made by some other investigators. For example, Landis (1951) extensively reviewed the literature on factors which influenced critical-flicker frequency (CFF). It was concluded that efficiency in this visual function was determined by the availability of blood-borne metabolites, such as blood sugar and oxygen in the retina, in the brain, or both. Chyatte (1959) confirmed these inferences of Landis in his studies His data indicated, that cortical nourishment affects electro-cortical and visual activities simultaneously. Chyatte's (1954, 1958) studies, indicated that alpha (index and amplitude) and CFF are significantly positively correlated.

Chyatte (1965) postulated that EEG- alpha index and CFF tend to diminish as people grow older because the atherosclerotic processes which are cumulative with aging decrease the blood flow as the lumen of the blood vessel narrows with cholesterol-laden deposits, thus cortical blood supply may be chronically impaired. His data bore out his predictions, and his findings also agreed with those of Obrist, et al (1963) who found alowing alpha frequency among older people, especially among those with atherosclerosis.

"Pierera (1959) points out that it is useful to distinguish massive displacement in the brain from localized blood shift. Massive blood shift in the brain seems clearly established in humans and in laboratory animals. The dizziness and blurred sensory input that people experience on arising from a cramped position is well known; these psychological symptoms reflect postural hypotension that develops when pressure on major blood vessels in the trunk is suddenly released to drain blood from the brain." Best and Taylor (1961) point out that "Deep breathing (hyperventilation) induces similar massive blood-shift symptoms in people; depletion of carbon dioxide lowers the tonic activity of the basomotor centers in the medulla, producing arteriolar dilation. Prolonged deep breathing thus can pool blood in lower parts of the body sufficient to cause dizziness or even fainting, since cerebral blood flow is decreased."

More meaningfully, blood-pressure effects are not always found to be related to other forms of massive blood-shift. For example, Ingvar (1958) points out that "induced general cortical arousal in cats via the brain-stem reticular formation, and through canalization, directly increases cortical circulation that is independent of blood pressure. It is recognized that this is evidence for a mechanism within the brain itself that regulates blood flow to accommodate changing metabolic demand under excitation. On this evidence, Ramon y Cajal's (reviewed earlier) conjecture of neuroglial contraction seems to gain credibility."

This intrinsic cerebral mechanism apparently underlies definite evidence of far more localized cortical blood shift. Working with cats, Schmidt (1950) "observed circumscribed hyperemia in the visual cortex when light was presented to the eye. "The work of Lorenzo, et al (1965) shows more evidence of localized blood shift " Lorenzo found selectively increased transport and penetration of the sulfate ion into auditory or visual brain loci appropriate to the end organ under sensory stimulation."

The work of Himwich (1951) illustrated that "in response to stimulation, an area of the brain goes into increased activity. The metabolism of that area must necessarily speed up to support the sudden burst of activity. The local manufacture and accumulation of carbon dioxide which always follows any increase in metabolism accelerates the flow of blood through the stimulated locus, thus satisfying its higher demand for oxygen. Such an adaptive vascular response is observed when the retina is stimulated by light and both the lateral geniculate body and the visual cortex show signs of increased blood flow."

In line with the previous inference that blood rivalry should be at a minimum between relatively separated cortical areas, and the fact that activation of any cortical locus results in massive blood shift to the brain as a whole; it is not unusual that a report such as that from Courts (1939) "facilitation of the learning of nonsense syllables by grasping a hand dynamoeter. The muscular tension may be said to increase blood flow not only to the somatosensory and somatomotor cortex, but also to parts of the brain that mediate verbal learning."

The work of Novak (1965) would also lead one to agree with Chyatte who says "quantitative aspects in the interaction of massive and local brain blood shifts await even more empirical scrutiny." The work of Novak gave evidence for rivalry even between comparatively distant loci. Novak found "that cutaneous electric shocks increased the tendency of people to perceive two briefly spatially separated flashes of light as one light."

# CHAPTER III

## DESCRIPTION OF THE APPARATUS

The testing device, used to measure the auditory threshold and induce the tone which each subject was exposed to, was a Beltone Audiometer Model 10 C (ASA Type). The unit was capable of measuring thresholds in descrete 1 db steps. Several pure frequency settings were possible, and the dial was set so that only discrete settings could be made, example: 50 cps, 75 cps, 100 cps, etc. The unit could deliver the tone constantly, or intermittently for a duration which could be varied according to the wishes of the examiner. Sound could be delivered either by "air" through earphones or by bone conduction. Sound could be delivered to either ear or both ears simultaneously. The dial which the examiner adjusted to increase the db amplitude was a quiet rotating type dial, adjustable in a smooth rather than clicking manner.

The electric shocks were administered from power obtained from a Stimulator Model 342 manufactured by the Harvard Apparatus Co. The oscillations were set in by clicking a rotating dial to discrete settings ranging from 5 through 25. Voltages were adjusted by rotary movement of a smooth dial calibrated in 5 volt steps normally marked on the apparatus. The examiner obtained at least consistent smaller "one volt" settings by dividing the 5 volt spaces each into "one volt" steps, which were then marked on the face of the unit. Voltage was delivered at a constant rate only, as opposed to delivery capability in an on-off manner. Voltage range was between 0 and 150 volts.

Amps are constant in this device, and very, very low.

To keep the resistance across the surface of each subject's skin uniform, EKG - Sol Electrode jelly was applied to points of the body where stimulation was to be applied. To mark the point on the body where the stimulation was to be applied, an indelible blue pencil was dipped into the jelly and a three-eighths inch diameter mark was made at each desired body point to be stimulated. Obviously it was not necessary to mark the place on the gums because that point was determined by its relative position to a given tooth.

The area used for testing thresholds was a regulation Audio Booth, Model 400 A, manufactured by the Industrial Acoustics Co., N.Y., N.Y. This unit has an excellent ventilation capability.

The devices used to apply shock, stimulation to the body, were to two kinds. Face, mouth, and neck areas were "stimulated" by a small wire piece with dimensions, 1/8 inch long and 1/16 inch wide. The "ground" wire piece was the same dimension and was located parallel to the "stimulation" wire at a distance of 1/8 inch, to allow easy placement of both probe wires, especially on the gums and tongue. For bilateral stimulation, an opposite set of identical probe wires could be adjusted and then fixed into place. The palm (with fingers 5,4) and thumb were "stimulated" by a copper plate 14 inches square, upon which a wet paper towel was placed to insure uniform current distribution. The ground was a small copper strip with dimensions, 2 inches long and 3/4 inch wide. The ground strip was held in place on the dorsal part of the hand or thumb by a snug rubber-band.

A stop watch with a 60 second sweep hand was used to time the length of stimulation application to any given body point and the length of time to which each subject received the tone at any given db level. For ease and convenience the stop watch was mounted.

Earphones were the padded adjustable aircraft type. A standard 6 inch diameter dental mirror was used by subjects to help them locate the probes onto body points to be stimulated. A combination centimeter and inches ruler was used to measure where various points to be stimulated would be located.

# CHAPTER IV

## PROCEDURE

<u>Subjects</u>: A total of 15 subjects, all white males, between the ages of 21 and 34, without history of ear, psychiatric and/or clinical disturbances, were studied. The purpose of an age limitation of 21 to 35 being stipulated, was to avoid the complex psychological and physiological changes due to maturation and ageing. The reason for an all white sample was to avoid the possibility of having skin resistance (due to pigment differences) cause problems in the application of shock levels. Other than the 21 to 35 age restriction, no other stipulations were made; therefore participation was based on willingness to participate and availability.

<u>Instruments</u>: It shall be useful to distinguish between; a) Experimental and Control Testing Conditions, and b) Sessions. a) The Testing Conditions number 17 in total The first condition was for control. The remainder were experimental.

1. Threshold measured without shock.
2. Threshold measured with shock to left cheek.
3. Threshold measured with shock to left upper lip.
4. Threshold measured with shock to left lower lip.
5. Threshold measured with shock to left upper gum.
6. Threshold measured with shock to left side of tongue.
7. Threshold measured with shock to left and right cheek simultaneously.
8. Threshold measured with shock to left and right upper lip simultaneously.
9. Threshold measured with shock to left and right lower lip simultaneously.
10. Threshold measured with shock to left and right upper gum simultaneously.

11. Threshold measured with shock to left and to right sides of tongue simultaneously.
12. Threshold measured with shock to left palm (with fingers 5,4).
13. Threshold measured with shock to left thumb.
14. Threshold measured with shock to left side of neck.
15. Threshold measured with shock to left and right palms, etc. simultaneously.
16. Threshold measured with shock to left and right thumbs simultaneously.
17. Threshold measured with shock to left and right sides of neck simultaneously.

The auditory threshold, with and without shock, is the dependent variable of this experiment. The electric shock is the independent variable. The unit of measurement for the dependent variable is the db as indicated on the previously described Beltone audiometer. The unit of measurement for the independent variable is voltage as indicated on the Harvard stimulator. The recording instrument, for all measures collected, was a simple score sheet. This score sheet indicated 5 scores (in db units) for any subject on each of the 17 testing conditions. The score sheet also showed the subject's upper threshold for being able to sustain a certain amount of volts which the subject himself determined. In other words, each subject was given 5 trials, and on each of these trials he stated when the shock had been increased to a level where he could maximally feel it and yet didn't require that the shock be removed from the particular body location. Shock was applied to each subject on 8 body locations. The specific location for each of the 8 body points shocked was;

1. Cheek- 2 cms below outside corner/s or eye/s.
2. Upper lip- 1 cm above corner/s of mouth.
3. Lower lip- 1 cm below corner/s of mouth.
4. Gum/s - Over the maxillary left lateral incisor.
5. Tongue- 2 cms back from the tip.
6. Palm (with fingers 5,4) - palmer surface. Fingers 3,2,1, were held, quite easily, off of the stimulation surface.

7. Thumb- Entire palmer surface extending back to the junction of the palm proper.
8. Neck- 10 cms below the junction of the earlobe and neck.

The instrument for determining these locations was a combination cm -inches ruler.

b) Session refers to the time period of testing for each subject on any given day. Each subject spent about 2 hours in testing in any session. There were four days of testing, or a total of 8 testing session hours for each subject.

Facilities: The entire testing program was conducted at the Dental Department of the United States 5th Army Medical Center at 5300 South Hyde Park, Chicago, Illinois, under the medical supervision of Dr. Van Collins (Col.). The testing area proper was the Audio Booth (described earlier) which allowed the testing sessions to take place in an environment which insured that the testing situation was constant for all control and experimental conditions with regard to factors such as: temperature, humidity, ambient noise (probably near zero db level), and general surroundings.

Experimental Design: The design called for 17 testing conditions, each administered 5 times to insure reliability. This means that each subject received a total of 85 recorded testing trials. The normal auditory threshold was established by 5 ascending trials which were recorded one after the other at the beginning of the first day session. Preceding these five recorded ascending trials each subject was exposed to the tone 20 times at a level where he could hear it. This was suggested and recommended by Dr. Laszlo Stein, M.D. and Audiologist so that the subject knew what he'd be listening for when he was given the 5 ascending trials which were to establish the normal threshold, and the later trials used for the experimental conditions.

On each of the 20 exposures used for this orientation, the db level was audible to start and then lowered to where the subject could no longer hear it and thus said "now." As was predicted by Dr. Stein, all subjects tended to no longer hear the tone after about 10 to 15 exposures, at a db level which stabilized and which indicated about where the ascending db normal threshold would be located. The tone was presented for 5 seconds at any given db level during the descending exposures and was turned on and off at about one second intervals during that interval

The remaining 80 trials were equally distributed over the 4 sessions, or 20 trails per session. These 80 trials were all in the experimental conditions category. Experimental conditions 2. thru 17, were administered randomly over these 80 trials until each subject had received 5 shocks on each body location. This design was felt to be the best, in order to rule out effects of psychological set, practice, fatigue, and application of shock according to a set sequence.

To insure that fatigue would not be a problem, many rest periods were given each subject, during each 2 hour session. A subject was given 3, 10 minute rest periods during a session. The testing-resting sequence followed a pattern such as 5 testing trials- 10 minute rest, 5 testing trials-10 minute rest, 5 trials- 10 minutes rest, 5 trials- go home. The session of the first day however was much busier, because in addition to the control condition 1, and 20 experimental trials being administered, tests were made to determine the maximally tolerable voltage for each body location which the subject was able to sustain. As was mentioned earlier, there were 5 such estimative trails recorded for this maximal judgement. To reach this judgement of maximally tolerable, it was necessary to first observe for 5 trials each, those points where the subject was first aware that some current was being applied to the body part, and that point at which he estimated the shock to be too much to sustain. Once a subject stated that the shock was too much, the examiner retarded the shock level very gradually until the subject said "that's better" and could thus sustain the shock level It is interesting to note that: a) most subject's were very consistent in their judgements of:

1. when there was some shock
2. the shock that was too much and
3. the immediately following judgment of when the shock had been reduced to a point where it was better and tolerable;

b) the judgement of too much shock was actually just slightly more than the recorded judgement of maximally tolerable to sustain. The 5 judgements of maximally tolerable to sustain were made one after the other, and after all of the 5 sequences where a sequence contained the judgements; something there, too much, better and sustainable. No record was kept on the something there, too much, better and tolerable sequences. The schedule for the first day busiest session was: administer 25 trials of which only the last five consecutive ascending trails were recorded for Control Condition 1.; administer 5 sequences which individually indicate judgements of something there, too much, better; administer 5 trails one after the other which indicate judgement of maximally tolerable to sustain; rest; start administering Experimental Conditions (randomly) following the previously described testing-resting sequence of 5 trials- 10 minutes rest, until 20 trials have been administered.

The arithmetic mean of five trials was the value used; a) to indicate the thresholds for control and experimental conditions, b) when it was time to actually adjust the voltage level to where it was considered to be maximally tolerable to sustain for any given body location. It should be pointed out that voltages were not only judged on the criterion of maximally tolerable to sustain but also on the estimate that voltages among various body locations were of roughly equal subjective intensity.

All arithmetic means calculated in this experiment were given with their Standard Error and Standard Deviations also indicated. The significance of the differences between mean performances of subjects on any given conditions was handled by t-ratio analysis. Prior to performing the t-ratio analysis, it was necessary to test for homogeneity of variance. This was accomplished by an F ratio.

For purposes of analyzing what the probability was for the gradient, in tactual-auditory rivalry, occurring in a progressively increasing hierarchy of means among subjects permutations were calculated.

<u>Method of Conducting Testing Sessions:</u> Each subject was tested individually and without distraction. Subjects were greeted on the first day and their name, age, and the best time for coming to future sessions was determined. Each subject was tested at exactly the same time for each session over the entire four day span. Subjects who may have had an opportunity to discuss the activities of the testing sessions, among themselves outside the testing sessions, were told not to do so. No subject was told anything concerning the purpose of the experiment. All apparatuses were set-up and ready to be used

upon the subject's arrival each day. Each subject was sitting and resting during every testing session.

To determine all recorded auditory and voltage (tolerances) thresholds, an ascending method was used. During the determination of all thresholds either auditory or voltage tolerance, the subjects' eyes were closed to prevent their watching activity of the examiner and to hopefully rule out confounding distractions and extraneous cortical activity. During the measurement of the normal auditory threshold (for five trials), the rate at which the dial was turned to gradually increase the db level in one db steps, was approximately 2 seconds between settings. Each subject was exposed to the constant 125 cps pure tone for a period of 15 seconds at any given db level During this interval the tone was turned off and on at approximately one second intervals This procedure was also recommended by Dr. Laszlo Stein of Michael Reese Hospital. Dr. Stein is the Chief Audiologist and Head of the E.E N.T. Department. When the subject heard the tone he was instructed to say "now." The tone was always induced by air into the left ear. When the subject stated that he had heard the tone, the examiner immediately returned the dial to a point of zero as indicated by the dial markings or to somewhere between zero and - 10. These "return" settings were varied randomly.

Once the above procedure had been used to obtain the normal hearing threshold the procedure for determining the voltage tolerances was begun. It should be pointed out that subjects were in contact with the "stimulation" apparatuses while the normal auditory thresholds were being obtained. The subjects, during the period of obtaining the normal auditory thresholds, had no idea of whether they were receiving current or not.

The oscillations were held constant on the Harvard Stimulator. The setting for oscillations was 10. Subjects were put at ease by the examiner by illustrating that he could receive certain voltages to his body without discomfort. During this procedure, of inducing shock to the examiner, the subjects were allowed to watch the rate and final positioning of the voltage induction and level, respectively. Once the subject had been put at ease, the locations for shock induction were determined by using the centimeter ruler and then making the 3/8 inch mark, at the appropriate place. Places to be tested for tolerance were selected at random for each subject. On any given body location, the examiner always started applying the voltage from a zero point. The rate at which the dial was turned was variable so that the subjects could get no time clue. The subject was instructed to say "now" the moment he felt anything at the point of stimulation. He was instructed to say "now" when the voltage was increased to too much. At the too much level the examiner retarded the shock level until the subject said (as instructed) "that's better," then the dial was set back to zero, and the entire procedure was repeated four more times, on the same body location. With completion of this latter sequence, the 5 consecutive judgements of maximally tolerable to sustain were made by the subject in the following manner. The experimenter started increasing the voltage from zero, and the subject said "now" the moment he felt something at the point of stimulation. The voltage was increased further until the subject again said "now," this point being (as instructed) the point where stimulation was maximally tolerable to sustain and roughly equally as intense as other stimulations. The maximally tolerable to sustain voltage level was maintained at the particular body location for 60 seconds, whereupon the examiner returned the dial to zero When all body parts had been tested for tolerance, on the first day session, the examiner started testing the subjects over the first sequence of 20 trials under the Experimental Conditions, by using the following method. The voltage was gradually increased from a zero starting point until it was set at the mean maximally tolerable to sustain level This voltage was applied for 60 seconds whereupon the examiner tapped the subject on the knee to indicate that the subject was to listen for the tone. When the subject heard the tone he said "now." At this point the examiner wrote down the threshold value which was indicated on the dial, then reset the dial to the randomly selected "return" starting point which was 0 to -20 inclusive. A new randomly selected body point for stimulation was stimulated, at its mean maximally tolerable to sustain level, just as soon as the subject located the proper place by looking into the dental mirror and had then closed his eyes. Obviously this placement of the stimulator by the subject was necessary only when head and neck areas were involved. This procedure: location of stimulation point, eyes closed, shock application, ascending db amplitude application, subject response, recording of response, and return of amplitude level to 0 to -20, was used for the 80 Experimental Condition trials.

## CHAPTER V

## PRESENTATION AND ANALYSIS OF FINDINGS

The columns of Table 1 below are arranged in an order which, from left to right, indicates their respective body areas' cortical locations, as distal to proximal, respectively, in relation to the auditory cortex. Each column number, with the exception of column 1., represents the corresponding experimental condition.

TABLE 1

PERFORMANCE VALUES IN DECIBEL UNITS FOR ALL SUBJECTS
UNDER UNILATERAL CONDITIONS (N=15)

| Columns= | 1. | 14. | 12. | 13. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|---|---|---|
| | NORMAL CONTROL | NECK | PALM ETC | THUMB | CHEEK | UPPER LIP | LOWER LIP | UPPER GUM | TONGUE |
| Means = | 7.59 | 9.00 | 10.08 | 11.21 | 10.17 | 11.01 | 11.65 | 12.44 | 13.57 |
| S.E. = | .65 | .78 | .79 | .80 | .72 | .73 | .76 | .72 | .72 |
| S.D. = | 5.61 | 6.78 | 6.84 | 6.94 | 6.27 | 6.31 | 6.60 | 6.22 | 6.24 |

From inspection of the above means, it would seem that caudocephally unilaterally applied electric shock to the skin does concurrently elevate the human auditory threshold. The significance of these elevations, however, is expressed better in terms of the significance of the difference between the normal auditory threshold values and corresponding threshold values as they are affected by experimental conditions. These differences are illustrated best in terms of percentage levels of confidence. We become more and more confident that the differences between two means did not occur by chance as we go from the lowest percentage confidence level ex: 10%, through to the highest, 1%. Levels of confidence throughout this dissertation will be illustrated in 10%, 5%, 2%, 1%. A t-ratio was computed between the mean of column 1. and each of the other column means above. The difference between means is significant at any particular confidence level if and only if the t value is greater than P. The P values throughout this dissertation for each of the confidence levels (with df 148) are as follows:

| Levels | .10 | .05 | .02 | .01 |
|---|---|---|---|---|
| P | 1.66 | 1.98 | 2.35 | 2.61 |

Before performing any of the t- ratios in this dissertation, an F ratio was calculated to determine homogeneity of variance, since t-ratio is an invalid test when the variances are not homogeneous. In this research the hypothesis that there is homogeneity of variance is rejected whenever F is greater than 1 61. No f in this entire research was greater than or equal to 1.61, therefore we accept the hypothesis that there is homogeneity of variance.

Table 2 below indicates the t-ratios and levels of significance between the mean of column 1 (the normal auditory threshold or control condition) and each of the means of the unilateral experimental conditions indicated by columns 14, 12, 13, 2, 3, 4, 5, 6. Data are based on 15 subjects.

TABLE 2

LEVEL OF SIGNIFICANCE FOR EACH EXPERIMENTAL CONDITION

| Columns | t-Value | Level of Significance |
|---|---|---|
| 1.and 14. neck | 1.40 | t P |
| 1.and 12. palm with fingers 5,4 | 2.44 | 2% |
| 1.and 13. thumb | 3.51 | 1% |
| 1.and 2. cheek | 2.66 | 1% |
| 1.and 3. upper lip | 3.50 | 1% |
| 1.and 4. lower lip | 4.06 | 1% |
| 1.and 5. upper gum | 5.00 | 1% |
| 1.and 6. tongue | 6.16 | 1% |

There are enough significant differences illustrated above to indicate that there is a cephalocaudal gradient in tactual-auditory rivalry, and that this gradient based on brain blood-shift, is much more extensive than the one observed in Chyatte's 1966 research.

The Column Arithmetic Means, shown below, represent the performance value (in db units) for all 15 subjects, under bilateral experimental conditions, and the control condition which appears as column 1.

| Columns = | 1. CONTROL | 17. SIDES OF NECK | 15. PALMS | 16. THUMBS | 7. CHEEKS | 8. UPPER LIPS | 9. LOWER LIPS | 10. UPPER GUMS | 11. SIDES OF TONGUE |
|---|---|---|---|---|---|---|---|---|---|
| Means = | 7.59 | 10.15 | 12.12 | 12.19 | 11.33 | 12.15 | 12.44 | 13.33 | 14.60 |
| S.E. = | .65 | .76 | .80 | .76 | .71 | .73 | .72 | .74 | .72 |
| S.D. = | 5.61 | 6.58 | 6.94 | 6.56 | 6.18 | 6.29 | 6.21 | 6.37 | 6.22 |

Inspection of the means on the preceding page shows that bilateral shock application also concurrently elevates the human auditory threshold. The bilateral shocking condition means also show a cephalocaudal gradient in tactual-auditory rivalry (based on blood-shift) which is very extensive. It would also seem that all these bilateral experimental condition means are significantly different from the control condition mean, because the lowest experimental bilateral mean is greater than a unilateral mean, which was significantly greater than the control mean, at the 2% level of confidence.

In regard to the closely located and cortically larger represented areas of the face and mouth, one very interesting phenomenon appears. The following hierarchy of means was found for both unilateral and bilateral shock:

no shock (lowest)

cheek

upper lip

lower lip

upper gum

tongue (highest)

Since six means can occur in many other hierarchical orders, the author decided to figure out the probabilities on the basis of permutations for such a combination of data to have occurred by chance. Six means can occur in six permutations; that is, there are 6x5x4x3x2x = 720 possible orderings. The probability of the theoretically predicted and verified ordering is thus 1/720 which is much better than the 1% level for the unilateral and for the bilateral taken separately. For both events to have occurred together, the number of permutations is 720x720x32 = 16,588,800. The value of 32 accounts for the two possibilities at each shock site: for example, either the unilateral cheek could be higher or the bilateral cheek could be higher. Since there are five shock sites, 2x2x2x2x2= 32. The probability that these blood-shift predictions could have occurred by chance is only 1 out of 16,588,800.

The results of unilaterally shocking areas separated about the head vs an area significantly separated from the head are indicated on the following page in terms of how they comparatively elevate the auditory threshold. First to be considered are several points which are separated from one another in the same general area of the face and which are also considered to be significantly separated from a single area distant from the head, on the lower part of the body, namely, the palm with fingers 5 and 4 simultaneously stimulated. Areas of the face to be considered are the cheek, upper lip, and lower lip, each of which shall be compared separately to the palm area. In order to maintain uninterrupted presentation of the analysis as much as possible, data (on means, S.E., and S.D.) are repeated below to negate the necessity of having the reader refer to preceding pages.

| Columns = | 12. | 2. | 3. | 4. |
|---|---|---|---|---|
| | PALM ETC. | CHEEK | UPPER LIP | LOWER LIP |
| S.E. = | .79 | .72 | .73 | .76 |
| S.D = | 6.84 | 6.27 | 6.31 | 6.60 |
| Means = | 10.08 | 10.17 | 11.01 | 11.65 |

| Columns | t Value | Level of Significance |
|---|---|---|
| 12.and 2. | .08 | t P Not significantly different |
| 12.and 3. | .86 | t P Not significantly different |
| 12.and 4. | 1.43 | t P Approaching the P value of 1.66 needed for 10% level of confidence |

It would seem from the data illustrated above, that the threshold elevation effects of unilaterally separately applied shocks to the cheek, upper lip, and lower lip are not singularily significantly greater than the effects of unilateral shock to the palm area. The t ratio analysis above shows that although the means are different in favor of the face areas which are closer to the auditory cortex, they are not significantly so. From one point of view, this development is not too surprising since it was considered at the beginning of this dissertation, that size of an area in the brain, and not merely proximity to the auditory cortex, may have some bearing on brain blood-shift. The stimulation of the palm area causes activation of a large area of the brain as can be seen in Figure 1. on page 7. When activated, this area, though somewhat distant from the auditory cortex, is probably large enough to cause significant brain blood-shift. This shift probably is great enough to "adversely" affect the auditory cortex, thus a significant elevation occurs in threshold as was seen when the unilateral shock to the palm area threshold mean was compared to the no shock normal auditory threshold mean. Activation of the palm area involves a much larger segment of the cortex than does activation of any of the single face areas; in fact if we look at Figure 1 page 7, we note that the palm area is apparently four times larger than either of the areas for upper lip or lower lip, and twice as large as the area of representation for the cheek which is part of the area designated as face in the diagram. It would seem as though the comparative effects of stimulation of the palm area or cheek, or upper lip, or lower lip do not differ from one another in their capacity to elevate the auditory threshold. This lack of significance of a difference in auditory threshold elevation capability could also possibly be explained by the fact that although these areas are quite separated on the body, they are nevertheless not too far distant from one another in the cortex. A look at the figure's diagram shows that the cheek area included in the face area in the diagram is very close to the palm area; thus it is not too surprising that their proximity plus the larger size of the palm area, causes about the same threshold elevation, and this is explainable probably on the basis of nearly equally disturbing influences on the auditory cortex. Lack of significant differences between the palm area and upper lip is probably due to the same type large size proximity relationship in the cortex, thus they have about the same affects on brain blood-shift. When the mean threshold differences between palm area and the lower lip are examined, they also are not significant, yet they approach significance at the 10% level. This almost significant difference in blood-shift capability, and thus almost significantly different capability to cause auditory cortex disfunction which favors the lower lip is probably explainable by the fact that the lower lip cortical area is very far from that of the palm area; and though much smaller, the lower lip area is very close to the auditory cortex, therefore because of its closer proximity, it can, according to theoretical assumptions, be very influential

The results of unilaterally shocking differentially sensitive parts of the body are indicated on the following page as well as on this page in terms of how they comparatively elevate the auditory threshold. Under consideration are the seemingly very sensitive area of the neck and the seemingly very tough area of the thumb. Earlier it was asked, if maybe the seemingly more subjectively sensitive area of the neck might, if shocked, cause a greater threshold elevation than that caused by shocking the thumb, even though the thumb cortical area is quite large and closer to the auditory cortex. Data on means, etc. are repeated below to facilitate ease of reading.

| Columns = | 14. | 13. |
|---|---|---|
| | NECK | THUMB |
| S.E. = | .78 | .80 |
| S.D. = | 6.78 | 6.94 |
| Means = | 9.00 | 11.21 |

| Columns | t Value | Level of Significance |
|---|---|---|
| 14. 13. | 1.97 | 10% (Approaching the P value of 1.98 needed for 5% level of confidence.) |

The data above show that the stimulation effects of the thumb when compared to influences of stimulation of the neck has the greater effect on the elevation of the normal auditory threshold. This is probably explainable due to the fact that the thumb cortical area is both much larger and much closer to the auditory cortex, than is the small, very distal (to the auditory cortex) neck cortical area. It would seem as though the effects of blood-shift are objectively demonstrated in this instance also, and that they apparently offset the questionable psychological effects.

The results of unilaterally shocking body areas; which differ on roughly all of the following criteria namely; separation about the head vs separation from the head, subjective sensitivity, and inside vs outside body, will now be compared, to see if they, when compared to each other are significantly differentially affective in elevating the auditory threshold. First to be considered are comparisons between the mouth areas (gums and tongue) and the cheek. Data on means, etc. are repeated to facilitate reading.

| Columns = | 2. | 5. | 6. |
|---|---|---|---|
| | CHEEK | UPPER GUM | TONGUE |
| S.E. = | .72 | .72 | .72 |
| S.D. = | 6.27 | 6.22 | 6.24 |
| Means = | 10.17 | 12.44 | 13.57 |

| Columns | t Value | Level of Significance |
|---|---|---|
| 2. and 5. | 2.23 | 5% |
| 2. and 6. | 3.33 | 1% (Well beyond the P value of 2.61 which establishes significance at 1%. |

The data on the preceding page and on this page clearly indicate that the proximity (to the auditory cortex) aspect of brain blood-shift theory, within the rationale of this experiment, has definite merit. The tongue cortical area, is the largest and closest area to the auditory cortex used in this study. Its influence in being able to disturb the function of the auditory cortex is quite outstanding. This was evidenced by the highest t ratio value of 6.16 between the normal threshold mean and the mean which reflected the influence of tongue stimulation on the normal auditory threshold. Only a t value of 2.62 would have been needed to show significance at the 1% level of confidence. The tongue was shown to be a very subjectively sensitive area because subjects were able to tolerate only a comparatively very small voltage application. For instance, subjects judged as maximally tolerable and roughly subjectively equal, an average voltage of 11 volts to the tongue as compared to about 60 volts applied to the seemingly sensitive neck. It will be recalled that no significant difference in threshold was caused by stimulation of the neck. This is probably because the neck is not as subjectively sensitive as is thought, and more important in blood-shift terms, the neck's cortical area is very, very small comparatively and quite distant from the auditory cortex. The tongue also seems quite (and more) subjectively sensitive when compared to the cheek; and is somewhat separated, and inside vs outside the body when compared to the cheek. The cheek, on an average, was found to be relatively "tough" because subjects could tolerate 50 volts. The data of the preceding page also do not seem to be in conflict with the separation, sensitivity, tissue location, and brain blood-shift factors just stated above. The significance of the difference between the elevation in auditory threshold produced by tongue stimulation and that produced by cheek stimulation is well beyond the 1% level and is in favor of the tongue effects. The effects of the same factors seem to be upheld quite well when the relationship between cheek and upper gum stimulation are considered. The stimulation effects for the upper gum are significantly greater than those of the cheek. This is evident by a t value of 2.23 existing between mean comparisons. The significance of this difference is greater than the 5% level of confidence.

Next to be considered will be the palm area compared to both the gums and tongue. These fall into the category of comparing stimulation effects between a body part which is significantly separated from the head vs areas about the head, plus seemingly differentially sensitive, and inside vs outside the body. The data resulting from these comparisons are indicated below.

| Columns = | 12. | 5. | 6. |
|---|---|---|---|
| | PALM ETC. | UPPER GUM | TONGUE |
| S.E. = | .79 | .72 | .72 |
| S.D. = | 6.84 | 6.22 | 6.24 |
| Means = | 10.08 | 12.44 | 13.57 |

| Columns | t Value | Level of Significance |
|---|---|---|
| 12. and 5. | 1.27 | t P |
| 12. and 6. | 3.26 | 1 % (Beyond the P value of 2.61 required for the 1% level.) |

The data above show that when the mean threshold differences between the palm area and the upper gum area are compared, there is no significant difference, even though the mean for the gum area is somewhat higher. The cortical area of representation for the upper gum is closer to the auditory cortex than is that of the palm area, however the upper gum area is very small; thus its "greater" disruptive effects on the auditory cortex are probably due mainly to proximity. The lack of significant comparative effects, though in favor of the upper gum stimulation disturbing influences, is probably due also to the fact that the palm areas cortical area is very much larger (apparently four times greater) than that of the upper gum, thus palm cortical area activation effects are very much the same as upper gum cortical area activation effects. The gums, if subjective sensitivity aspects can be considered, are much more sensitive than the palm area. Voltage tolerance to the gums was merely 14 volts on the average, while tolerance for the palm area was 85 volts.

The data above also illustrate the outstandingly greater comparative effect of tongue cortical area activation on the auditory threshold. When tongue stimulation auditory effects are compared with the palm area stimulation auditory effects, those of the tongue are significantly much greater. In this instance the tongue is cortically in a competitively influential category when size of its area is compared to that of the also large palm area. However, the tongue is the closest cortical area under study in this dissertation, and when compared to the palm cortical location from the auditory cortex there is no basis for competition. The palm area is very far from the auditory cortex. Therefore the greater influences of the tongue seem to be a combination of size and proximity. Also the tongue, as was mentioned, is very sensitive, subjects only being able to tolerate 11 volts applied to it. The palm area is seemingly quite "tough" because subjects could tolerate 85 volts applied to it.

Data are presented below which show how the auditory threshold is comparatively affected by unilateral cortical activation of areas which have been previously designated to test the proximity vs size aspect of the brain blood-shift theory. For the sake of brevity, S.E. and S.D. will not be repeated.

Columns= 12. 6.

PALM ETC. vs TONGUE

Large-distant vs Large-close

Means = 10.08 13.57

t Value = 3.26 Significant beyond the 1% level of confidence.

This comparison has been discussed before when the author analyzed these two body areas and how they compare with one another relative to their positions along the cephalocaudal gradient. The tongue stimulation has the greater effect because it is just about as large as the palm area, and it is the closer cortical area in relationship to the auditory cortex.

Columns= 4. 6.

LOWER LIP vs TONGUE

Small-close vs Large-close

Means = 11.65 13.57

t Value = 1.83 Significant beyond the 10% level of confidence.

The influence of shocking the tongue is greater than that of shocking the lower lip. It is interesting that such a small cortical area as the lower lip could be more of a rival to the area of the tongue than is the largest area, the palm area. The comparisons above 12. and 6.; 4. 6. therefore add to the "argument" that the proximity aspect of brain blood-shift theory is probably more significant or relevant than is the size aspect. To this point; it would seem that to have the size aspect become comparatively relative in blood-shift terms, the large distant cortical area activated must be necessarily a composite of many smaller areas, activated by stimulation of many discrete body points. The effect, of this arrangement of cortical stimulation, seems to be somewhat competitive only with the effect which stems from activation of a very small cortical area, which is in turn somewhat and arbitrarily considered close to the auditory cortex.

| | | | |
|---|---|---|---|
| Columns= | 14. | | 13. |
| | NECK | vs | THUMB |
| | Small-distant | vs | Large-close |
| Means = | 9.00 | | 11.21 |

t Value = 1.97 Significant well beyond the 10% level of confidence. Approaching the P value of 1.98 needed for the 5% level of confidence.

It has been shown previously that the neck cortical area has no seemingly significant brain blood-shift capability because its effects on the auditory threshold were not significant. Its capability to cause relatively insignificant brain blood-shift probably lies in the fact that it is both a small area and is far removed from the auditory cortex. The greater influence of the thumb cortical area lies in the fact that it is large and relatively close to the auditory cortex.

| | | | |
|---|---|---|---|
| Columns= | 14. | | 12. |
| | NECK | vs | PALM ETC. |
| | Small-distant | vs | Large-distant |
| Means = | 9.00 | | 10.08 |

t Value= .97 Not nearly significant--not even close to the P value of 1.63 needed for the 10% level of confidence.

Both of these body areas have cortical centers which are relatively very far from the auditory cortex. These cortical areas are very close to one another in the cortex, thus it is not surprising that there is very little comparative difference in their effects on elevation of the auditory threshold. It would seem that the somewhat greater effect produced by the palm area is due to its size and closer proximity to the auditory cortex.

| Columns= | 14. | | 4. |
|---|---|---|---|
| | NECK | vs | LOWER LIP |
| | Small-distant | | Small-close |
| Means = | 9.00 | | 11.65 |

t Value = 2.43 Significant beyond the 2% level of confidence.

This comparison is significant in favor of the lower lip and is significant also because it illustrates again that when size of cortical areas compared, is equal, the closer area to the auditory cortex will be the most influential

| Columns= | 12. | | 4. |
|---|---|---|---|
| | PALM ETC. | vs | LOWER LIP |
| | Large-distant | vs | Small-close |
| Means = | 10.08 | | 11.65 |

t value = 1 43 Approaching the P value of 1.66 needed for the 10% level of confidence.

The difference above is in favor of the cortically more proximite lower lip, although not significantly so. As was stated earlier, it is believed that the lack of significant differences between these areas, lies in the fact that cortically the palm area is very very large by comparison with the lower lip area. It is believed that the effects of the two areas, caused by their relative larger size vs closer proximity, are somewhat balanced out, due to a somewhat equal brain blood-shift capability.

Data in Table 3 illustrate the comparative effects of unilateral vs bilateral stimulation of any set of body areas, such as; neck stimulation on one side vs stimulation of both sides, palm stimulation vs stimulation of the palms, thumb vs thumbs, and so on. Only parts of the body involved, t values, and any significance levels, need be reported in order to maintain brevity of the presentation

TABLE 3

COMPARISON OF PERFORMANCE UNDER UNILATERAL AND BILATERAL STIMULATION

| Areas | t Value | Level of Significance |
|---|---|---|
| Neck vs both sides of neck | 1.06 | t P Not significantly different |
| Palm vs palms | 1.82 | t P Significant beyond the 10% level of confidence |
| Thumb vs thumbs | .89 | t P Not significantly different |
| Cheek vs cheeks | 1.15 | t P Not significantly different |
| Upper lip vs upper lips | 1.14 | t P Not significantly different |
| Lower lip vs lower lips | .75 | t P Not significantly different |
| Upper gum vs upper gums | .86 | t P Not significantly different |
| Tongue vs sides of tongue | 1.01 | t P Not significantly different |

Although, as was seen earlier, all mean elevations for the bilateral stimulation were observed to be higher than those of the unilateral stimulations, it would appear that they are not significantly higher, except in the case of the palm areas. This significance of a difference, with regard to the palms stimulation, is probably caused by the comparative largeness of the areas involved. From the other means presented earlier, all that can be said as to whey they were not significantly different in favor of the bilateral stimulations, is, that possibly if the size of the sample were increased, the levels of significance would probably be increased, thus the assumption that more blood is shifted by bilateral stimulation, would be even more tenable.

The means for bilateral stimulation were presented earlier in this chapter, thus they need not be presented again. However, it was shown that these means did follow a definite hierarchical order, which could have occurred by chance, only one time in 720, which is better than the 1% level of confidence. The existence of a definite pattern of a cephalocaudal gradient in tactual-auditory rivalry is thus established for bilateral stimulation.

An analysis of data based on unilateral large-close vs large-distant, and bilateral large-close vs large-distant type comparisons for all possible combinations indicated earlier under the topic of size vs proximity, will not be needed because it was found that in general bilateral effects are usually greater than unilateral effects; as was seen when comparisons were made between the neck and sides of the neck, thumb and thumbs, cheek and cheeks, etc. If these individual body parts show greater "sensitivity" reflected by greater threshold elevation, to bilateral shock, then there would be greater "sensitivity" shown in any case where these parts' effects form a composite effect.

# CHAPTER VI

## SUMMARY AND DISCUSSION

Summary: The purpose of this research was to investigate the influences of tactually applied electric shock on the human auditory threshold. Under study were the effects of several cortical areas which mediate the sensitivity of the body areas which were shocked, located in such a way in relation to the auditory cortex, that their influence on the auditory cortex was postulated to be maximal to minimal, as their distance from the auditory cortex was considered to be close to, quite distant, respectively. It was theorized that the auditory threshold would be concurrently elevated as tactual shock was applied caudocephally, and that there would be shown to exist an extensive cephalo-caudal gradient in tactual-auditory rivalry which stemmed from the shifting of blood in the brain to a sensitivity area quite distant from the auditory cortex (ex: the toe), thus causing very little disturbance in auditory function, vs the shifting of blood to an area quite close to the auditory cortex (e.g. the tongue) thus causing a maximal auditory disturbance. Body areas which were shocked were selected primarily because of their cortical positions relative to the auditory cortex, but other factors interesting to note are that a) the cortical sequence is inverted for body areas such as the toes, foot, leg, hip, shoulder, arm, fingers, face, lips, teeth, gums, and tongue in such a way that the closest body cortical area to the auditory cortex is that of the tongue, b) one body area, located in the region of the head, namely the neck, has its cortical area very distant from the auditory cortex, thus it appears to be the one exception to the predominantly inverted cortical arrangement, c) more seemingly subjectively sensitive body parts, which are located about the head and whose tissues are usually inside the body such as the gums, teeth, and tongue, are closer to the auditory cortex and have what appear to be disproportionately larger areas of cortical representation when compared to large body areas such as the entire body trunk whose cortical area of representation is much smaller than would be expected, d) neck area, which is seemingly a very sensitive area in the head region, has a cortical area which is very small, in fact smaller than the cortical area for the thumb which would seem to be a very insensitive body part; thus the neck seems again to be the exception to the "rule" that head region body parts which are seemingly more sensitive, have larger cortical areas of representation, e) influence of large size of cortical area, of the closer (to the auditory cortex) tongue, gums, lips, and face, was questioned, because it was thought that for instance, the face cortical area when activated exercised greater auditory disfunction capability than could the shoulder area, not because of its closer proximity, but because of its greater size. All of these factors; in summary, cortical size vs cortical proximity, subjective sensititity, separation about the head region or vs separation from the head area, and tissue location inside vs outside the body, were also taken into consideration when the areas to be stimulated were selected. It was postulated that brain blood-shift influences based on primarily the proximity aspect, would be shown to produce the expected progressively increasing hierarchy of means for auditory threshold which in turn would show the existence of the cephalocaudal gradient in tactual-auditory rivalry. It was thought that the size aspect would be shown to be definitely not as influential as the proximity aspect, if influential at all. It was believed that the remaining factors, named above, could be shown as complementary rather than in conflict with the proximity oriented brain blood-shift influences. Also under investigation was the comparative effects of bilateral sensory cortical area activation vs unilateral sensory cortical area activation, on the auditory threshold; to see if the former produced greater threshold elevation effects and to see if these elevations formed a progressively increasing hierarchy of auditory threshold means. The domain of body parts to be stimulated, in order to investigate all areas proposed in this study, was the neck, palm (with fingers 5 and 4), thumb, cheek, upper lip, lower lip, gums, and tongue. The order above shows greatest distance from the auditory cortex to closest proximity to the auditory cortex, respectively. Stimulation of each of these body parts, unilaterally and bilaterally, formed the basis for experimental conditions; thus there were 16 experimental conditions. The order of presentation for these experimental conditions was randomly varied, until each subject received 5 shocks on each body part unilaterally and bilaterally. The control condition was the normal auditory threshold which was established by five consecutive trials using an increasing db level of sound induction to the left ear, by air method. Sound induction under experimental conditions was also by ascending db level, by air, and always to the left ear. Subjects were always seated, at rest, and had their eyes closed during all sound inductions. Shock amps, and oscillations were held constant, and only voltage was varied over 5 pretest trials to an eventually constant level which each subject judged to be maximally tolerable to sustain, at any particular body location. All other factors in the testing situation such as temperature, humidity, etc. were held constant. The dependent variable may thus be considered to be the auditory threshold. The independent variable is the tactually applied electric shock.

The general findings were:

1. The unilateral and bilateral caudecephalo application of electric shock to the skin does concurrently elevate the human auditory threshold.
2. The assumption, that activation of sensory cortical areas closest to the auditory cortex will have the greatest effect in producing concurrent auditory disfunction due to brain blood-shift from the auditory cortex to these adjacent areas, seems to have been borne out.
3. The existence of an extensive cephalocaudal gradient in tactual-auditory rivalry based on brain blood-shift; and illustrated by a progressively increasing hierarchy of auditory threshold means which corresponds to the cortical activation sequence, example, farthest from the auditory cortex through to the closest to the auditory cortex, respectively, has been shown for both unilateral and bilateral stimulation conditions.
4. The proximity of cortical areas to the auditory cortex was shown to have a greater effect than did the size of cortical area activated.
5. The effect of bilateral stimulation was shown to be somewhat greater than that of unilateral stimulation. Thus the assumption that bilateral activation of sensory cortical areas on both hemispheres will cause greater blood-shift than merely activation of one hemisphere, seems to have some merit.
6. In all cases, except one incidental factors which seem to contribute to the subjective sensitivity of a given body part, factors such as location in the region of the head or separation significantly from the head, and tissue location inside vs outside the body, seemed to complement the physiological proximity oriented brain blood-shift influences. Only the neck body area was found to be an exception. It was surprisingly "tough" in its ability to withstand shock. However, in strictly proximity oriented brain blood-shift terms, the unilateral neck stimulation did not have significant effect on the auditory threshold, as could have been expected, due to the large cortical distance between the neck cortical area and the auditory cortex.

The findings of this study have turned out to be well within the expectations of the author, especially in regard to the predicted existence of the very extensive cephalocaudal gradient in tactual-auditory rivalry. The findings also are in general agreement with those of Chyatte's (1966) research.

Some suggestions can be offered in order that future research can be even more enlightening concerning the Brain-Blood-Shift Theory.

Research should be undertaken which will explore the effects of shock application to many more parts of the body than were used in this experiment. Of particular interest would be the application of shock to parts of the body such as the back of the throat and intra-abdominal areas, to see if their stimulation would lead to an even higher elevation of auditory threshold than was caused by stimulation of the tongue. These body parts have the closest cortical proximity to the auditory cortex. Of course, such shock application would require very close and much more sophisticated medical supervision than was needed for this research. Ideally, the domain of body parts to be stimulated in future research should extend from toes through intra-abdominal, and should explore the effects of shock application to very small discrete areas of any given body part and total stimulation of any given body part. The effects of stimulating combinations of many parts of the body which have cortical areas adjacent to one another should also be investigated to further explore the proximity vs size aspect of brain blood-shift theory.

One specific change would be particularly interesting for future research. This would entail application of a different type of tactual stimulation; namely, heat or pin points. The latter type of stimulus would especially avoid the creation of some of the possible misleading ideas which subjects may get as could possibly occur in the use of electric shock, not that this latter stimulus caused problems in this research. No subject, during this entire experiment, expressed any undue discomfort upon the application of the maximally tolerable to sustain shock application. In fact 11 of the subjects stated, at the end of the total procedure, that they were no longer as deluded concerning the anticipated effects of electric shock, at low amperage, as they had been.

Some research should be done concerning the rate of blood flow in and about various areas of the brain cortex. After this had been done, future researchers would have a better idea as to how long the stimulus need be applied to the skin before the introduction of the sound. The "time needed" for the blood to shift into the areas under stimulation may thus be found to be even shorter than the one minute adaptive period used in this research.

# CHAPTER VII

# CONCLUSIONS

It may be concluded that:

1. Caudocephally tactually applied electric shock does concurrently elevate the human auditory threshold (i.e., the shock reduces the acuity in hearing). As shock is applied caudocephally, there is evidenced a corresponding progressively increasing hierarchy of auditory threshold means which indicates the existence of a very extensive cephalocaudal gradient in tactual-auditory rivalry.

2. These effects verify Chyatte's Brain Blood-Shift Theory which postulates that neighboring parts of the cerebral cortex compete for their blood supply, the effect becoming more pronounced for brain loci that are relatively close, and less pronounced for loci that are relatively far apart.

3. Suggestions for future research have been offered.

## CHAPTER VIII

## BIBLIOGRAPHY

Beckman, H. Pharmacology (2nd ed). Philadelphia: Saunders, 1961, 643.

Best, C. H. and Taylor, N. B. The Physiological Basis of Medical Practice. Baltimore: Williams and Wilkins, 1961, 392.

Carlin, S., Ward, W. D., Gershon, A. and Ingraham, R. Sound stimulation its effect on dental sensation thresholds. Science, 1962, 138, 1258-1259.

Castiglioni, A. A History of Medicine. New York: Knopf, 1947, 135.

Chyatte, C. The relation of cortical potentials to perceptual functions. Genet. Psychol. Monog., 1954, 50, 189-226.

Chyatte, C. A note on the relationship of alpha index to critical flicker frequency. Electroencephalography and Clin. Neurophysiol., 1958, 10,

Chyatte, C. Perceptual set and critical flicker frequency. Amer. J. Ophthal., 1959, 48, 352-355.

Chyatte, C. Brain blood-shift theory: A preliminary test through correlations of age with alpha EEG and CFF. J. Psychol., 1965, 61, 27-32.

Chyatte, C. Unconscious. Encyclopedia Britanica., 1967, in press.

Chyatte, C. Brain blood-shift: Verification of a predicted gradient in tactual-auditory rivalry. Science, 1966, in press.

Courts, F. A. Relations between experimentally induced muscular tension and memorization. J. Exp. Psychol., 1939, 25, 235-256.

Darrow, C. W. and Graf, C. G. Relation of electroencephalogram to photometrically observed vasomotor changes in the brain. J. Neurophysiol., 1945, 8, 449-462.

Fulton, J. P. Observations upon the vascularity of the human occipital lobe during visual activity. Brain., 1928, 51, 310-320.

Glover, M. B et al Isolation and mechanical maintenance of the dog brain. Nature., 1965, 206, 94.

Himwich, H. E. Brain Metabolism and Cerebral Disorders. Baltimore: Williams and Wilkins, 1951, 104.

Ingvar, D. H. Reticular Formation of the Brain. Boston: Little, Brown, 1958, 176-183.

Kennedy, J. L. A possible artifact in electroencephalography. _Psychol. Rev._, 1959, 66, 347-352.

Landis, C. Something about critical flicker fusion. _Scientific Mo._, 1951, 73, 308-314.

Lorenzo, A. V., Fernandes, C., Roth, L. J. Physiologically induced alteration of sulfate penetration into the brain. _Arch. Neurol._, 1965, 12, 128-132.

Novak, S. The effect of electrocutaneous digital stimulation on the detection of single and double flashes of light. _Psychol. Monog._, 1965, No. 608.

Orbist, W. D., _et al._ Relation of EEG to cerebral blood flow and metabolism in old age. _Electroencephalography and Clin. Neurophysiol._, 1963, 15, 610-619.

Penfield, W. and Rasmussen, T. Further studies of the sensory and motor cerebral cortex in man. _Fed. Proc. Amer. Soc. Exp. Biol._, 1947, 6, 452-560.

Perera, G. A. A Textbook of Medicine. Philadelphia: Saunders, 1959, 1199.

Ramon y Cajal, S. Algunas conjecturas sobre el mechanismo anatomico de la ideacion. _Revista Medica y Cirugia Practicas._ 1895, 36, 479-508.

Schmidt, C. F. The Cerebral Circulation in Health and Disease. Springfield, Ill.: Thomas, 1950, 37-45.

Shepard, J. F. Organic changes and feeling. _Amer. J. Psychol_, 1906, 17, 522-584.

Stevens, S. Handbook of Experimental Psychology. New York: Wiley Inc., 1951, 137-138.

Symons, J. R. The effect of various heteromodal stimuli on visual sensitivity. _Quart. J. Exper. Psychol._, 1963, 15, 243-251.

Zubek, J. P. and Welch, G. Electroencephalographic changes after prolonged sensory and perceptual deprivation. _Science_, 1963, 139.

# APPROVAL SHEET

The dissertation submitted by Robert M. Shannon has been read and approved by the members of the Department of Psychology.

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the dissertation is now given final approval with reference to content, form, and mechanical accuracy.

The dissertation is therefore accepted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

December 12, 1966
Date

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Signature of Adviser